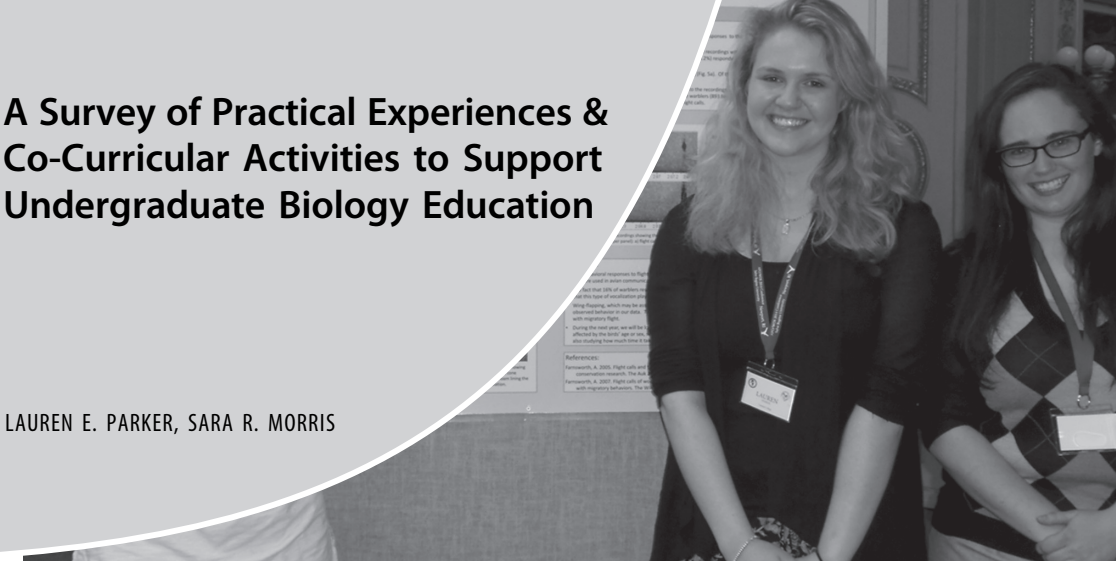
FEATURE ARTICLE

A Survey of Practical Experiences & Co-Curricular Activities to Support Undergraduate Biology Education



LAUREN E. PARKER, SARA R. MORRIS

Abstract

Active-learning experiences – in classrooms, laboratories, and outside of courses – are highly valued components of preparing undergraduates to become biologists. We characterized the educational opportunities available to students in the biological sciences at colleges and universities within the eastern Great Lakes region and student perceptions of a variety of opportunities. We surveyed biology departments at 33 institutions to determine the availability of and participation in educational travel, internships, laboratories, skill development, and undergraduate research involvement. There was variation in the availability of internships, the types of skill development and educational travel offered, and the numbers of labs required in different biology curricula. Undergraduate research was offered at all institutions, and most research-active students presented results at least locally. Most colleges and universities offer a wide range of educational experiences and opportunities that complement traditional biology curricula and that are valued by students. Because fewer than half of the students took advantage of most of these experiences, schools still have the opportunity to increase their value in undergraduate education through increased student participation.

Key Words: *Undergraduate biology education; active learning; undergraduate research; internship; skill development; educational travel; laboratories.*

Introduction

In recent decades, there has been a noticeable paradigm shift in biology educational strategies, with emphasis moving from curricula based on passive learning to curricula largely based on active learning (e.g., National Research Council, 2003; Brewer & Smith, 2011). Furthermore, active-learning activities can increase success in biology (Leonard, 2000; Freeman et al., 2007; Armbruster et al., 2009). In the sciences, a variety of active-learning experiences and co-curricular activities can provide students opportunities to apply the theoretical knowledge they learn in a classroom setting (e.g., Prichard & Sawyer, 1994).

Laboratory courses give students the opportunity to learn and practice standard lab techniques as well as data analysis and presentation.

Learning through application regularly occurs in laboratory courses in the sciences (e.g., Prichard & Sawyer, 1994). Laboratory courses give students the opportunity to learn and practice standard lab techniques as well as data analysis and presentation. Laboratory courses can also be used to provide authentic research experiences, modeling the processes of science and increasing students' interest in science in general and in future research (Kloser et al., 2011; Brownell et al., 2012). Additionally, laboratory courses may include educational travel, in the form of field trips that enhance the understanding of concepts learned in the classroom (Spicer & Stratford, 2001; Lei, 2010).

Biology students can further develop their skills through undergraduate research or internships. Undergraduate research provides students more in-depth experiences in biology and can increase their confidence and their likelihood of pursuing science careers (Lopatto, 2004; Hunter et al., 2007; Russell et al., 2007; Thiry et al., 2011). Research experiences provide undergraduates with practical experience and skills vital to a successful career in the sciences, including proficiency in a variety of laboratory and/or field techniques, the ability to generate and test hypotheses, and an understanding of how to critically read primary literature. The value of these research experiences can be further enhanced by participation in research conferences where students can present their research results (Chopin, 2002; Mabrouk, 2009). Likewise, internships have been shown to increase students' skills and knowledge and to result in more student interest in pursuing science careers (Scholz et al., 2004; Hodder, 2009; Thiry et al., 2011).

Educational opportunities outside of a traditional classroom setting enrich the educational experience for students, giving them

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a deeper knowledge and an increased confidence in their abilities. Although these experiences have demonstrated value in biology education, there is only limited data on whether these experiences are incorporated into undergraduate biology curricula. The goal of this article is to describe the educational opportunities available to undergraduates in the biological sciences, the prevalence of these activities at colleges and universities, and students' perceptions of them. Specifically, we focused on opportunities available at institutions within the eastern Great Lakes region in New York, Pennsylvania, and Ohio.

○ Methods

To obtain information about the educational opportunities offered, we conducted a survey of the department heads of 88 institutions in New York, Pennsylvania, and Ohio. These institutions were located within a 200-mile radius of our own institution, Canisius College, and all offered a four-year undergraduate degree in biology. We identified these institutions using the College Board's college search tool. We sent out the original request and two additional follow-up requests to each of the targeted institutions.

The survey assessed the educational opportunities available both within and outside the curriculum in each of these programs. Areas evaluated included research seminars, professional skill development, undergraduate research involvement, laboratory experiences, internships, and educational travel opportunities. The survey included questions with several different forms of responses, including multiple-choice options, ordered categorical options, and open-ended text boxes. For each category of educational experience, we asked the respondents to identify whether their program offered it, whether or not it was required for students to successfully complete the program, and when in their college careers students typically participated in it. Because of possible differences in the educational opportunities available to undergraduates at different types of institutions, we present data separately for primarily undergraduate institutions (PUIs) and graduate-degree-granting institutions (GDGIs), although, given the small sample sizes, we generally do not focus on differences between these types of institutions. We summarize quantitative data as means ± SD. During analysis, we occasionally omitted the answers to specific questions from one or two institutions because of the ambiguity of their responses.

○ Results

Thirty-three department heads responded to our survey on undergraduate biology programs. Of these respondents, 25 (75.8%) directed programs that granted solely undergraduate degrees (i.e., PUIs), and 8 (24.2%) directed programs that conferred graduate degrees in the biological sciences as well as undergraduate degrees (i.e., GDGIs). The typical annual number of undergraduate degrees granted by these departments ranged from 12 to 100 at the PUIs and from 24 to 250 at the GDGIs.

Types of experiential learning common in biology curricula include laboratories, internships, and educational travel. The surveyed institutions had an average of 4.4 ± 2.5 labs that were required of all undergraduates for successful completion of the biology program. Institutions reported that 53.0 ± 32.4% of upper-level electives also had required laboratories, 14.0 ± 25.3% of electives had optional laboratories, and 33.0 ± 25.8% of upper-level electives did not have corresponding laboratories. Internships were common, but not ubiquitous. Credit-bearing internships were available at 69.7% of the institutions surveyed (Table 1). Despite how frequently they were offered as an educational option, they were not commonly required in biology curricula, with only 21.2% of institutions mandating that students complete at least one internship before graduating from the program. At most schools (63.6%), fewer than a quarter of the students in the biology program took part in internships. Educational travel was a form of experiential learning offered by all institutions surveyed, although the opportunities varied among institutions (Table 1). The most common form of educational travel was local and/or regional, with 100% offering this experience, and 84.8% offered national travel

Table 1. Availability of educational opportunities in biology programs at colleges and universities in the eastern Great Lakes region. Data are the percentage of institutions indicating the availability of each opportunity to students majoring in the biological sciences. The data were obtained by surveying department heads in New York, Pennsylvania, and Ohio during spring 2015.

Opportunities	Primarily Undergraduate Institutions (N = 25)	Graduate Degree-Granting Institutions (N = 8)
Educational Travel		
Local and Regional Travel	100.0	100.0
National Travel	88.0	87.5
International Travel	76.0	50.0
Internships	68.0	75.0
Departmental Research Seminars	68.0	87.5
Professional Development		
CV Development	48.0	37.5
Oral Presenting	92.0	50.0

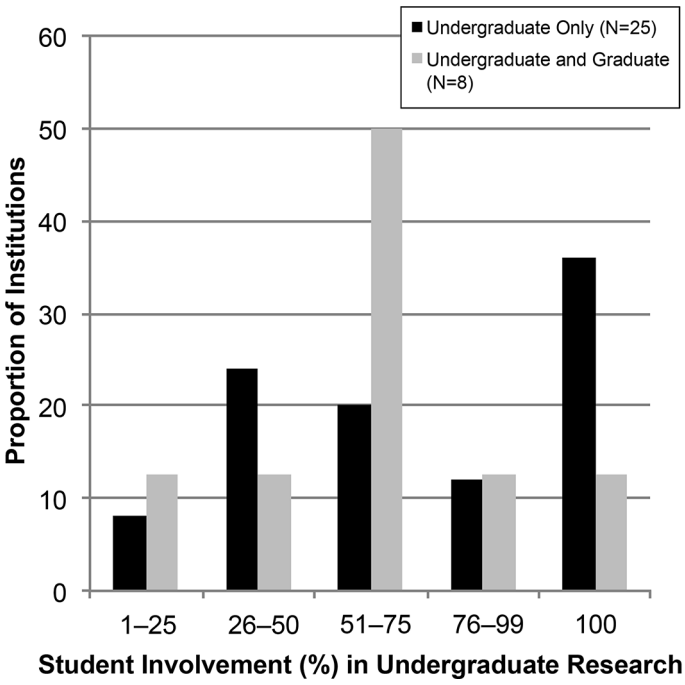

Figure 1. Student involvement in undergraduate research at the institutional level at colleges and universities in the eastern Great Lakes region (N = 33). Each institution was asked to provide the percentage of students majoring in the biological sciences that participate in undergraduate research. Bars indicate the proportion of institutions within each of these categories. The data for this table was obtained by surveying department heads in New York, Pennsylvania, and Ohio during spring 2015.

opportunities. In addition, international travel opportunities were available at 69.7% of institutions.

Undergraduate research occurred at all institutions surveyed. The majority of the institutions reported that over half of the undergraduates within their program participated in some undergraduate research (Figure 1). Furthermore, 30.3% of all institutions surveyed reported that 100.0% of program graduates participated in research. More than half of the institutions (54.5%) reported that most or all of their research-active students had experience with designing their own experiments. In addition, 72.7% indicated that most or all students presented research results at on-campus events. While all institutions indicated that at least some of their students presented at discipline-specific conferences, only 6.0% reported that most of their undergraduates presented at discipline-specific conferences. All respondents indicated that some graduates of their programs had published their undergraduate research in academic journals (Table 2).

Many of the programs surveyed expected students to attend and/or give seminars as part of their curriculum. Most institutions expected students to give oral presentations (Table 1). Although most programs required their students to give oral presentations, a relatively low proportion of institutions required attendance at research seminars. Only about a third of the institutions surveyed required attendance at departmental research seminars for successful completion of the biology program.

In addition to attending and giving seminars, other professional skills are incorporated into biology curricula. Additional required skills reported by the institutions were variable. These included curriculum vitae (CV) development, interview skills, grant writing, experimental design, and proficiency in programming and statistical software packages, among others. CV development was required by 45.5% of the responding institutions in the students' sophomore year (33.3%), in the junior year (46.7%), or in the senior year (20.0%).

Although our sample size is small, we found some differences in the educational opportunities available at PUIs and GDGIs. For instance, internships and research seminars were more prevalent at GDGIs. Furthermore, 32.0% of PUIs did not offer departmental research seminars. By contrast, international travel and professional skill development were more common at PUIs. For example, oral presentations were required by more of the PUIs in the biological sciences (92.0%) than the GDGIs (50.0%). In terms of undergraduate research participation, the proportions of students who designed their own experiments, presented data on campus, and published results in academic journals were similar between PUIs and GDGIs. However, a higher proportion of students at GDGIs practiced standard lab techniques, while a higher proportion of students at PUIs presented research results at regional or discipline-specific conferences.

○ Discussion

Although our sample size is small (33 institutions), the results of our survey regarding undergraduate education illustrate substantial variation and common themes. All surveyed institutions offer laboratory coursework, educational travel, and undergraduate research opportunities, and most offer professional skill development and internships (Tables 1 and 2). The prevalence and commitment to co-curricular activities across institutions reflects the perceived importance of these activities to faculty and institutions for training biology students. Brief surveys of some Canisius College undergraduates and recent graduates suggest that different students valued different experiences, suggesting the importance of providing a range of opportunities when trying to make the best educational experiences for a variety of students, especially for those with different future goals.

In the sciences, laboratory components of classes provide logical opportunities for applied, experiential learning. The number of laboratories required by biology curricula varied from 2 to 10 in our sampled institutions, indicating a wide range of required hands-on experiences across undergraduate biology curricula. At Canisius, biology students tend to take more laboratory courses than are required, indicating that students value these experiences. Laboratory courses offer students the opportunity to learn and practice standard laboratory techniques, which gives them skills that they can use in future careers. Laboratories can also allow students to develop a deeper understanding of how science works, especially through authentic research experiences. Kloser et al. (2011) provides a framework for using a faculty member's research program to create research-based laboratories. Utilizing this method, students focused on open-ended research questions that have no "correct" answer rather than following a pre-designated procedure to get a specific desired result. In a comparison of student outcomes between "cookbook" labs and authentic

Table 2. Summary of undergraduate research involvement at the institutional level at colleges and universities in the eastern Great Lakes region. Data are the percentage of institutions indicating each level of involvement by their students majoring in the biological sciences in each activity. The data were obtained by surveying department heads in New York, Pennsylvania, and Ohio during Spring 2015.

Activities	None	Some	About Half	Most	All
Primarily Undergraduate Institutions (N = 25)					
Standard Lab Technique	0	36	20	36	8
Designing Own Experiments	0	20	24	36	20
Presenting Data					
On Campus	0	16	12	20	52
Regional Conferences	0	48	28	20	4
Discipline-Specific Conferences	0	72	20	8	0
Publishing Results	0	100	0	0	0
Graduate Degree-Granting Institutions (N = 8)					
Standard Lab Technique	0	37.5	0	37.5	25
Designing Own Experiments	0	37.5	12.5	50	0
Presenting Data					
On Campus	0	0	25	50	25
Regional Conferences	0	62.5	37.5	0	0
Discipline-Specific Conferences	0	100	0	0	0
Publishing Results	0	100	0	0	0

research-based labs, Brownell et al. (2012) found that students in authentic research-based labs gained experience with, and confidence in, interacting as part of a collaborative research team, developing and testing hypotheses, analyzing and interpreting data, and writing a scientific report. The faculty member using authentic research-based laboratories can benefit because the lab produced additional data and hypotheses that could be used in the research group (Kloser et al., 2011). Thus, undergraduate biology curricula that include laboratory courses incorporating authentic research experiences can provide additional benefits to both students and faculty.

As is the case with laboratories, educational travel gives students the chance to apply the concepts they have learned in the classroom. Educational travel can take many forms, including short class field trips (frequently within a laboratory period), slightly longer class trips (on weekends or during breaks), field courses often taught entirely on location away from the university, and co-curricular trips not associated with specific coursework. Field experiences allow students to observe and experience ecological concepts (Janovy & Major, 2009), and they have been shown to increase students' ecological knowledge (Hamilton-Ekeke, 2007). The recognized value of these experiences is reflected in that all surveyed institutions included local or regional travel, and most included national or international travel in their curricula (Table 1). Furthermore, Spicer and Stratford (2001) found that the experiential value of actual field trips could not be replicated using virtual field trips.

Professional skills are a common component of biology curricula or co-curricular activities, according to our survey. Understanding and presenting scientific data are vital skills for all biology majors, regardless of career path. Brownell et al. (2012) found that students gained confidence in their ability to communicate about science in research-based laboratory courses. These skills can also be augmented through a variety of other means, including reading primary literature, attending research presentations, giving seminars, and completing independent research projects (described below). All institutions offered opportunities for students to gain these scientific literacy skills. Because biological knowledge is changing rapidly, biology students are often valued not for their knowledge but for their competencies, which include critical thinking, information literacy, statistics, and/or specific computer or software proficiency. Incorporating these skills into biology curricula can be used both to produce well-prepared graduates and as a recruiting tool. Although highly valued by students and alumni at Canisius, CV development was required by fewer than half of the institutions surveyed as part of their curriculum. Preparing a CV serves not only as an educational experience for students, but also advertises the strengths of a program because it effectively conveys the experiences and skills students have acquired during their time in the program.

Internships provide students the opportunity to explore different career options, and most schools offer these opportunities for course credit (Table 1). However, at 64% of the institutions surveyed, fewer than a quarter of the students took advantage of this opportunity. It is possible that internships are more common than reported, because institutions may not have reported non-credit-bearing internships and/or "internships" that are called by other names (e.g., shadowing physicians or other professionals, volunteering in professional settings, part-time work experience). Hodder (2009) indicates that field stations

provide research and practical internships, which gives students additional educational opportunities away from the college campus. Scholz et al. (2003) found that internships not only enhanced the scientific abilities of participants, but also increased valuable professional skills such as effective communication and organization.

Perhaps one of the best forms of experiential education for training science students is independent hypothesis-driven research. Lopatto (2004) surveyed over a thousand students from 41 institutions and found that research experiences enhanced both their general satisfaction and the learning gains of their undergraduate educational experience. Research opportunities were offered universally among our surveyed institutions (Table 2); in approximately one-third of them, research was required for graduation. Furthermore, students recognized the value of research experience, as shown by the majority of institutions reporting 50% or more class involvement (Figure 1). Based on a survey of University of Delaware alumni, Bauer and Bennett (2003) reported that research involvement increased cognitive skill development. Furthermore, Hathaway et al. (2002), Bauer and Bennett (2003), and Russell et al. (2007) have found that students engaged in undergraduate research were more likely to attend graduate school than non-researchers. Independent research provides students the opportunity to do background research, generate hypotheses, carry out experiments, analyze data, and communicate the results, both orally and in writing. In our survey, almost three-quarters of institutions reported that most or all research students presented their results locally (Table 2). However, most institutions reported that only some of these research students presented either regionally or at discipline-specific conferences. Likewise, all institutions reported that only some students published their research results. Thus, there is the opportunity for institutions to increase the benefit of these experiences for students, either through increasing student participation or increasing the dissemination of results through presentations and/or publications. This is particularly important because these activities can increase students' commitment to continuing in the sciences (Russell et al., 2007; Mabrouk, 2009).

Interestingly, many students do not make use of all of the opportunities offered by their institution. Because undergraduate biology majors may be preparing for a variety of different career paths (professional school, graduate school in the sciences, jobs in the sciences, teaching, etc.), it is possible that the experiences valued differ among students. When evaluating the experiences offered to undergraduates at postsecondary institutions, it is important to keep in mind that there is a difference between availability, accessibility, and participation. Increasing accessibility – whether it be through increased dissemination of information regarding opportunities to undergraduates within the programs or through increased funding to facilitate student involvement – may substantially increase the numbers of students who are able to participate and thus benefit from these opportunities.

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LAUREN E. PARKER is a graduate of the Biology Program at Canisius College, 2001 Main St., Buffalo, NY 14208; e-mail: parker23@canisius.edu. SARA R. MORRIS is a Professor of Biology at Canisius College; e-mail: morriss@canisius.edu.